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ONE PRINCIPLE FOR THE OPERATION OF AN ORBITAL ASTRONOMICAL OBSERVATORY CONTROLLED BY A COSMONAUT

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ABSTRACT. The paper deals with the problem of obtaining high-precision astronomical observations using an astrophysical observatory installed in a multipurpose orbital station and manned by a cosmonaut who is not a professional astronomer. The principal concern is to level the telescope, or telescopes, outside the spacecraft at the proper star without programmed assignment when the spacecraft is more or less arbitrarily oriented with respect to the sky. The problem is solved by using an additional optical aiming tube set against one of the ports in the spacecraft and by introducing a primary follow-up system of rough sighting between the aiming tube and the telescope. Potentiometers are used as position (or angle) sensors. The cosmonaut levels the aiming tube at the proper star and the primary system points the telescope at the same star with an accuracy of ±0.5°. This is sufficient for the proper star to be caught by the photoguide, set on the telescope, which automatically tracks the star with high precision. This marks the beginning of the programmed work of the telescope controlled by an on-board programming device.

With the appearance of spacecraft and orbital stations controlled by cosmonauts new possibilities are arising for conducting astrophysical observations under exoatmospheric conditions. First of all, on such stations it is possible to place larger telescopes and other astronomical instrumentation. Second, the presence in an orbital station of a cosmonaut, even if he is not a professional astronomer, will make it possible to formulate an observation program which is broader and more complex than when control of the observatory rests entirely on an automatic system operating with a completely predetermined, preestablished and unmodifiable program. /5*

The cosmonaut's role is particularly important in cases when astronomical observations are made by the photographic method, on photographic films or plates. Despite all the inconveniences and difficulties of a technical nature in using photographic materials, the advantages of the photographic method itself for making exoatmospheric observations must be regarded as beyond question. The

* Numbers in the margin indicate pagination in the foreign text.

photographic method is and remains the most effective, and at times an indispensable means in those cases when there is a need for collecting a mass of information from extensive regions of the star sky, when studying the macrostructure of extensive celestial objects, investigating their fine structure with a high angular resolution, etc.

In addition, there are indications that photographic materials cannot survive too long, for example, several months, in space; they will be fogged. However, orbital stations and observatories are designed for many months of active operation in space, with periodic replacement of the station's crew. Evidently the solution to this problem is the periodic, such as once a month, return of magazines with expended photographic film to the earth, and in return, delivery of fresh photographic film to the orbital station, with its subsequent insertion /6 in the magazines and plate holders of telescopes and spectrographs.

We visualize a large observatory in orbit, supplied with all the necessary means for conducting autonomous and programmed work, that is, conducting astronomical observations without presence of a cosmonaut. Naturally, in principle it would be conceivable to create such systems which would make it possible after implementing the observational program to separate the magazines with exposed photographic films from the orbital telescopes, deliver these magazines to earth and then implement the reverse process, delivery to the orbital observatory of new magazines with fresh photographic films, docking of a transport ship to the observatory and insertion of the magazines in the telescopes and spectrographs by means of manipulators. But all this will be complex, unwieldy, and possibly unreliable.

The operations involved in replacing the magazines and photographic films must be included among those which can be accomplished far more easily and reliably by a cosmonaut with use of minimum automation. Even the partial performance of these operations by a cosmonaut, for example, only the separation of magazines with exposed photographic film from telescopes for the purpose of its subsequent dispatch to the earth without the insertion of new magazines, can be accomplished considerably more effectively than by use of automatic devices.

Finally, the most important consideration is control of the operation of an astrophysical observatory by a cosmonaut. Regardless of the specific scientific problems whose solution can be assigned to an orbital station, it is entirely clear that in the overwhelming number of cases the observatory must be placed outside the spacecraft or orbital station. This is true in all those cases when the telescope is either very large or the apparatus, regardless of its size, is intended for the detection of radiation in the far ultraviolet region (shorter than 2000 Å) and X-ray range. Only in individual cases, when an instrument with a small aperture is designed for operation in the region longer than 2000 Å, can it also be placed within the orbital station, in front of one of its windows fabricated from pure quartz.

The tasks of a multipurpose orbital station naturally cannot be limited to ensuring the necessary conditions only for normal operation of the astrophysical observatory carried aboard it. For example, it is impossible to require that the orbital station always and with a high accuracy occupy a very definite orientation over a long period of time relative to stellar coordinate systems; in this case all would be simpler because using a simple programming attachment it would be possible to turn and aim the telescope at any region accessible with the station in its particular position.

Accordingly, it is important to find a solution of the next more general /7 problem: pointing the telescope or telescopes on the necessary star and on the necessary region of the sky without a programming attachment or with more or less arbitrary orientation of the spacecraft relative to the sky. In other words, the problem arises of identifying a celestial body (object) in the sky towards where the telescope must be directed.

Identification of an object in the sky and pointing of the telescope at it must be regarded as the first and most important task which can be solved more effectively by a cosmonaut making astronomical observations in orbit.

The task can be formulated more rigorously in the following way. The telescope with its mounting and auxiliary apparatus is situated outside the spacecraft and is attached to its body. The cosmonaut always remains within the spacecraft and does not have direct access to it, in a spacesuit or through a special lock. Moreover, the telescope is situated even outside the cosmonaut's field of view during normal scanning through the ship's windows. It is necessary that the cosmonaut by means of a remote control system direct the telescope on the necessary object in the sky with the stipulated accuracy and with subsequent checking on its precise tracking (guidance) after the object. Below we will discuss one possible principle for practical solution of this problem.

This principle is based on the use of an additional telescopic finder mounted opposite on of the ship's windows and the introduction of a primary tracking system for rough pointing between this telescopic finder and the telescope mounting. As the position (or angle) sensor it is possible to use potentiometers mounted in a pair on the axes of the mountings of both systems, finder telescope and telescope.

Figure 1 is a general diagram of both system components. The finder telescope 1 with a field of view 5-6° is mounted in front of the window 2 to the spacecraft's body by means of a support and can be rotated about the axes ω_1 and ω_2 by means of a small mounting. Not far from this site, the telescope 5 and a biaxial mounting 6 are attached directly to the spacecraft's body 4 and in the space external to it; the mounting can also make rotational motions around the axes ω_1 and ω_2. It is important that the corresponding axes of the mountings, of the finder and the telescope, be parallel to one another with an accuracy of about 10' of arc. Moreover, the axes of rotation of both mountings, of the sight and telescope, are electrically connected to one another (the conventional dashed lines in Figure 1), that is, with the tracking system of the guide. Then any rotation of the finder about an axis, such as ω_2, by the angle φ, will correspond to the same rotation of the telescope about this same axis (Figure 1).

Bearing in mind the difficult conditions for the cosmonaut's work in orbit, /8 the low resolving power of the finder telescope, and the need for the relatively rapid search for and interception of the necessary star, especially during oscillation of the ship, it is impossible to expect that with such a method the telescope would be pointed at the necessary star with an accuracy better than ±0.5°. Therefore, a stellar biaxial photoguide 7 with a field of view of about 3°, considerably greater than the accuracy of interception with the telescope (now already with the photoguide) of the star A, is attached to the telescope parallel to its optical axis. As soon as the desired star A appears in the photoguide field of view, the fine pointing tracking system is automatically triggered, which, already operating independently of the primary tracking system, reduces this star to the optical axis of the photoguide (telescope) and accomplishes automatic tracking after it with the stipulated accuracy (minutes or seconds of arc). With movement of the star A into the photoguide field of view the pointing tracking system is disconnected from the finder telescope and telescope mounting. Shifting of the

telescope into a regime of precise tracking after the star, that is, appearance of the star on the optical axis of the star photoguide, is registered by lighting of a small electric lamp on the control panel for the entire system, which is situated alongside the finder telescope. At this time the cosmonaut presses the button for triggering the programming device which also programs all subsequent telescope operation, that is, photographing the object with a stipulated successive exposure. /9
For shifting to another star the telescope tracking system is deactivated, the primary tracking system of the finder telescope is activated, and the entire process begins again.

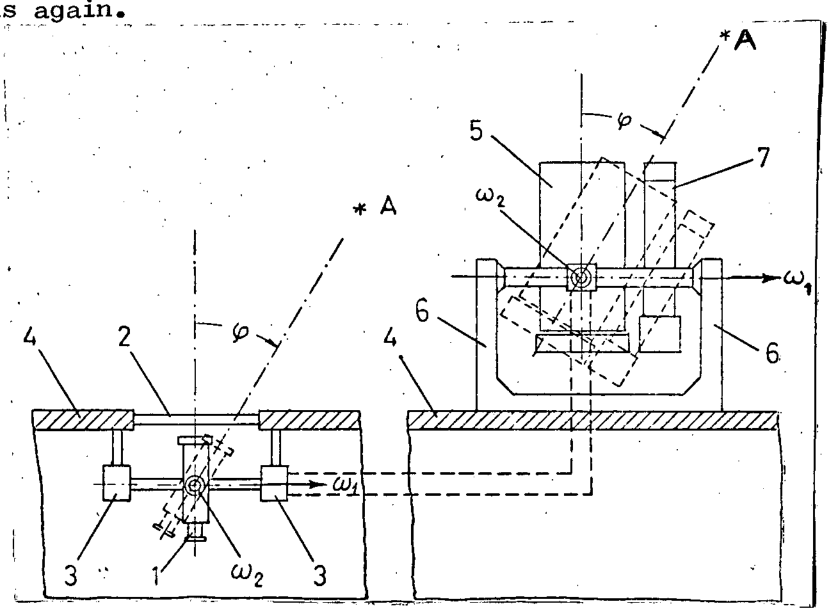

Figure 1. Schematic diagram of control of telescope operation (at right) by means of its forced pointing at the star A using a sighting (finder) system (at left).

With respect to the finder telescope angle of view, within whose limits it is possible to search for and intercept the necessary star, it is dependent on the size of the window and finder telescope. For practical purposes this angle can be rather large, about ±30°. This is simultaneously the limiting angle of oscillation of the orbital station admissible during observatory operation.

The described principle for control of operation of the orbital observatory by a cosmonaut was applied as the basis for developing the "Orion" system installed in the "Salyut" orbital station and designed for obtaining individual spectrograms of stars in the region of wavelengths 2000-3800 Å.

In the "Orion" system the role of the cosmonaut involves primarily identification of the necessary object (star) in the sky and pointing the finder telescope at it. Tracking of the star with the stipulated accuracy, exposure, as well as programming of telescope operation, are accomplished automatically, without the cosmonaut's intervention.

One of the principal problems formulated during the first flight of the "Orion" space observatory was in-space checking of the practicality and viability of the already described principle of observatory operation with control by a cosmonaut, not a professional astronomer, but one who had undergone some training on the earth. In this work it was necessary to ensure the required accuracy of the collected scientific data and reliability of operation of the automatic systems and kinematic units.

As shown by an analysis of data from the first "Orion" flight on the "Salyut," the operating principle for the orbital observatory used as its basis, which included work by a cosmonaut, completely justified itself and in the future can be used in developing larger space observatories.

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